SUPPLEMENTAL MATERIAL

Soil Phosphorus Modeling for Modern Agriculture Requires Balance of Science and Practicality: A Perspective

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**The EPIC model**

The EPIC model was developed primarily to investigate the effects of soil erosion by wind and water on crop production and crop growth in the U.S.A. (Williams et al., 1983). As the application of the EPIC model broadened, the name changed to the Environmental Policy Integrated Climate (also EPIC) model (Williams, 1995). The EPIC soil P sub-model incorporates soluble and particulate soil P erosion and relationships between labile, active, stable and organic P pools (Jones et al., 1984). In EPIC, labile P is defined as a combination of P extracted by anion exchange resin, initial organic P and an index of the availability of fertiliser P (Sharpley et al., 1984). Labile P for initialisation is calculated using a linear relationship with the amount of P extracted by several methods (Sharpley et al. 1984). To simplify the initialisation process, relationships were developed to estimate the size of each P pool for three main soil categories: calcareous, highly weathered and slightly-weathered soils from across North America (Sharpley et al., 1984, 1989). Updates to the P model and methods to improve initialisation have included modifications to equations controlling P flow between labile and non-labile pools (Vadas et al., 2006) and P sorption capacity (Bolster and Vadas, 2018). The EPIC soil P model has been used to assess P cycling in Swiss agro-ecosystems (Della Peruta et al., 2014) and has been incorporated into large scale geospatial assessments in the U.S.A. (Wang et al., 2012) to estimate global P losses from major cultivated crops (Liu et al., 2018).

**The DSSAT model**

The DSSAT model includes a sub model to simulate P dynamics and crop uptake in a range of P deficient soils including highly weathered and calcareous soils. It has been calibrated and tested from datasets for soybean and maize in Colombia, Syria and Tanzania and Kenya (Daroub et al., 2003; Dzotsi et al., 2010), maize in Ghana (Naab et al., 2015) and sorghum in Mali (Adam et al., 2018). The DSSAT soil P sub-model incorporates complex P fractions including labile, active and stable fractions in plant roots, P in senesced shoots and
roots, metabolic and structural forms of P in organic fractions (Daroub et al., 2003). The labile-P pool includes both soil-solution P and loosely sorbed P and can be initialised by measures of resin-extractable P (Daroub et al., 2003), extractable P and exchangeable potassium (K) (Singh, 1985; Dzotsi et al., 2010) or, the equations developed by Sharpley et al. (1984, 1989). The equilibrium constants between pools are based on those from EPIC (Jones et al., 1984). For simulating acidic soils, DSSAT requires contents of iron and aluminium oxides, or aluminium saturation; for alkaline soils, CaCO$_3$ content is required. Data on soil pH and texture is required for simulating all soil conditions. A water erosion sub-model and a sediment-bound P model were also incorporated to calculate P losses in the U.S.A. (Egeh, 2004).

**The APSIM model**

The APSIM Model is based on modelling efforts in the mid 1980’s by Probert (1985) to simulate the effects of N and P in low input maize systems in Kenya where the nutrient sources are often not commercial fertilisers but rather manures and biomass (Probert, 2004). The soil P sub-model also includes options for using mineral and rock phosphate fertilisers and banding P fertilisers at depth. The mineral P pools are either stable or labile and the organic P pools cycle along with the N and C pools. The conceptual labile pool in the model is defined as the amount of P in solution and sorbed to the soil surface (but not tightly bonded) (Wang et al., 2013). Fertiliser P only contributes to this pool when it is broadcast. The labile pool not directly linked to a particular soil test for initialisation allowing the user to define the method of quantification (Delve et al., 2009). The model has been calibrated and tested in maize systems in Kenya (Probert, 2004; Delve et al., 2009), maize-bean cropping rotations in Colombia with various fertiliser regimes (Delve et al., 2009), sorghum crops with a combination of manure and mineral fertilisers in Ghana (MacCarthy et al., 2009), mixed cropping rotation system in Australia (Wang et al., 2014). APSIM was also used to
incorporate the effect of root citrate efflux on soil P availability (Wang et al., 2013) and for wheat in Pakistan (Ahmed et al., 2018).

References


